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ABSTRACT

This teacher's guide, with accompanying videotape, presents an episode of the NASA SCI Files. In this episode, one of the tree house detectives has had an accident and cannot get into the tree house. Using problem-based learning, the rest of the gang investigates the world of simple machines and physical science and "pull" together to get everyone into the tree house. The scientific concepts addressed in this episode include numbers and measurement, geometry, data analysis and probability, problem solving, communication, representation, unifying concepts and processing, science and inquiry, life science, earth and space science, science and technology, history and nature of science, the world in spatial terms, places and regions, physical systems, human systems, and environment and society. The guide is divided into four segments with the following sections: overview; objectives; vocabulary; video component; careers; resources; and activities and worksheets. (YDS)

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Educational Product	
Educators	Grades 3-5

EG-2002-07-12-LARC

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The NASA SCI Files™
The Case of the Powerful Pulleys

A Lesson Guide with Activities in Mathematics, Science, and Technology

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Please Note: Our name has changed! The NASA "Why" Files is now the NASA SCIence Files™ and is also known as the NASA SCI Files™.

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The Case of the Powerful Pulleys lesson guide is available in electronic format through NASA Spacelink - one of NASA's electronic resources specifically developed for the educational community. This publication and other educational products may be accessed at the following address: **http://spacelink.nasa.gov/products**

A PDF version of the lesson guide for NASA SCI Files™ can be found at the NASA SCI Files™ web site: **http://scifiles.larc.nasa.gov**

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The NASA SCI Files™ The Case of the Powerful Pulleys

A Lesson Guide with Activities in Mathematics, Science, and Technology

Program Overview 5
National Science Standards 6
National Mathematics Standards 8
National Technology Standards 9

Segment 1

Overview 11
Objectives 12
Vocabulary 12
Video Component 13
Careers 13
Resources 14
Activities and Worksheets 15

Segment 2

Overview 25
Objectives 26
Vocabulary 26
Video Component 26
Careers 27
Resources 28
Activities and Worksheets 28

Segment 3

Overview 39
Objectives 40
Vocabulary 40
Video Component 40
Careers 41
Resources 41
Activities and Worksheets 42

Segment 4

Overview 51
Objectives 52
Vocabulary 52
Video Component 52
Resources 53
Careers 53
Activities and Worksheets 53

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Registered users of the NASA SCI Files™ may request a Society of Women Engineers (SWE) classroom mentor. For more information or to request a mentor, e-mail **kim.tholen@swe.org**

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Program Overview

Accidents happen and Jacob has broken his foot. He is eager to get back into the tree house and join his friends, but the cast on his foot prevents him from climbing the ladder. The tree house detectives decide that devising a plan to get Jacob safely into the tree house will be their next case, and so begins *The Case of the Powerful Pulleys.*

As the tree house detectives research ways to get Jacob safely into the tree house, they visit Dr. D to learn about work, force, and energy. They decide that it is going to take a lot of energy to do the work needed to lift Jacob up to the tree house! There must be an easier way.

Dr. Textbook introduces the tree house detectives to the world of simple machines. Now they think they are getting somewhere. Dr D invites them to visit him at a circus to learn more about simple machines. At the circus, they think they have solved the problem. However, the tree house detectives know that they need to do a lot more research before they jump to any conclusions.

The tree house detectives set off to visit NASA engineers at NASA Langley Research Center and NASA Dryden Flight Center. Bianca is excited to learn more about engineers because she is preparing a report for Career Day. The Society of Women Engineers (SWE) helps the NASA SCI Files™ Kids Club in Raleigh, North Carolina provide valuable information about pulleys to the tree house detectives. With that information and after a trip to Legoland®, they think they are ready to solve the problem.

Come join the tree house detectives as they learn about simple machines, force, energy, work, and the world of engineering to discover that "pulling" Jacob up into the tree house is not as "simple" as they thought.

National Science Standards (Grades K - 4)

Standard	Segment 1	2	3	4
Unifying Concepts and Processes				
Systems, orders, and organization	✖	✖	✖	✖
Evidence, models, and explanations	✖	✖	✖	✖
Change, constancy, and measurement	✖	✖	✖	✖
Evolution and equilibrium	✖	✖	✖	✖
Science and Inquiry (Content Standard A)				
Abilities necessary to do scientific inquiry	✖	✖	✖	✖
Understanding about scientific inquiry	✖	✖	✖	✖
Physical Science (Content Standard B)				
Properties of objects and materials	✖	✖	✖	✖
Position and motion of objects	✖	✖	✖	✖
Life Science (Content Standard C)				
Characteristics of organisms			✖	
Organisms and their environments			✖	
Science and Technology (Content Standard E)				
Abilities of technological design	✖	✖	✖	✖
Understanding about science and technology	✖	✖	✖	✖
Science in Personal and Social Perspective (Content Standard F)				
Personal health			✖	✖
Science and technology in local challenges	✖	✖	✖	✖
History and Nature of Science (Content Standard G)				
Science as a human endeavor	✖	✖	✖	✖

National Science Standards (Grades 5 - 8)

Standard	Segment 1	2	3	4
Unifying Concepts and Processes				
Systems, order, and organization	✖	✖	✖	✖
Evidence, models, and explanations	✖	✖	✖	✖
Change, constancy, and measurement	✖		✖	✖
Evolution and equilibrium	✖			
Science as Inquiry (Content Standard A)				
Abilities necessary to do scientific inquiry	✖	✖	✖	✖
Understanding about scientific inquiry	✖	✖	✖	✖
Physical Science (Content Standard B)				
Motion and forces	✖	✖	✖	✖
Transfer of energy	✖	✖	✖	✖
Science and Technology (Content Standard E)				
Abilities of technological design	✖	✖	✖	✖
Understanding about science and technology	✖	✖	✖	✖
Science in Personal and Social Perspectives (Content Standard F)				
Personal health			✖	✖
Risks and benefits			✖	✖
Science and technology in society	✖	✖	✖	✖
History and Nature of Science (Content Standard G)				
Science as a human endeavor	✖	✖	✖	✖
Nature of science	✖	✖	✖	✖
History of Science		✖		

National Mathematics Standards (Grades 3 - 5)

Standard	Segment 1	2	3	4
Number and Operations				
Understand numbers, ways of representing numbers, relationships among numbers, and number systems.	✖	✖	✖	✖
Understand meanings of operations and how they relate to one another.	✖	✖	✖	✖
Compute fluently and make reasonable estimates.	✖	✖	✖	✖
Algebra				
Understand patterns, relations, and functions.			✖	
Represent and analyze mathematical situations and structures using algebraic symbols.	✖	✖	✖	✖
Use mathematical models to represent and understand quantitative relationships.			✖	
Analyze change in various contexts.			✖	
Measurement				
Understand measurable attributes of objects and the units, systems, and processes of measurement.	✖	✖	✖	✖
Apply appropriate techniques, tools, and formulas to determine measurements.	✖	✖	✖	✖
Data Analysis and Probability				
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.			✖	
Develop and evaluate inferences and predictions that are based on data.			✖	
Problem Solving				
Build new mathematical knowledge through problem solving.	✖	✖	✖	✖
Solve problems that arise in mathematics and in other contexts.	✖	✖	✖	✖
Apply and adapt a variety of appropriate strategies to solve problems.	✖	✖	✖	✖
Monitor and reflect on the process of mathematical problem solving.	✖	✖	✖	✖
Communication				
Organize and consolidate mathematical thinking through communication.		✖		
Communicate mathematical thinking coherently and clearly to peers, teachers, and others.		✖		
Connections				
Understand how mathematical ideas interconnect and build on one another to produce a coherent whole.	✖	✖	✖	✖

National Technology Standards (ITEA Standards for Technology Literacy, Grades 3 - 5)

Standard	Segment 1	2	3	4
Nature of Technology				
Standard 1: Students will develop an understanding of the characteristics and scope of technology.	✖	✖	✖	✖
Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.	✖	✖	✖	✖
Technology and Society				
Standard 6: Students will develop an understanding of the role of society in the development and use of technology.	✖	✖	✖	✖
Standard 7: Students will develop an understanding of the influence of technology on history.		✖		
Design				
Standard 8: Students will develop an understanding of the attributes of design.	✖	✖	✖	✖
Standard 9: Students will develop an understanding of engineering design.	✖	✖	✖	✖
Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.	✖	✖	✖	✖
Abilities for a Technological World				
Standard 11: Students will develop the abilities to apply the design process.	✖	✖	✖	✖
Standard 12: Students will develop abilities to use and maintain technological products and systems.	✖	✖	✖	✖
Standard 13: Students will develop abilities to assess the impact of products and systems.	✖	✖	✖	✖
The Designed World				
Standard 16: Students will develop an understanding of and be able to select and use energy and power technologies.	✖	✖	✖	✖
Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies.	✖	✖	✖	✖
Standard 20: Students will develop an understanding of and be able to select and use construction technology.			✖	✖

National Technology Standards (ISTE National Educational Technology Standards, Grades 3 – 5)

Standard	Segment 1	2	3	4
Basic Operations and Concepts				
Use Keyboards and other common input and output devices efficiently and effectively.	✖	✖	✖	✖
Discuss common uses of technology in daily life and the advantages and disadvantages those uses provide.	✖	✖	✖	✖
Technology Productivity Tools				
Use general purpose productivity tools and peripherals to support personal productivity, remediate skill deficits, and facilitate learning throughout the curriculum.	✖	✖	✖	✖
Use technology tools for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.	✖	✖	✖	✖
Technology Communication Tools				
Use technology tools for individual and collaborative writing, communication, and publishing activities to create knowledge products for audiences inside and outside the classroom.	✖	✖	✖	✖
Use telecommunication efficiently and effectively to access remote information, communicate with others in support of direct and independent learning, and pursue personal interests.	✖	✖	✖	✖
Use telecommunication and online resources to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.	✖	✖	✖	✖
Technology Research Tools				
Use telecommunication and online resources to participate in collaborative problem-solving activities for the purpose of developing solutions or products for audiences inside and outside the classroom.	✖	✖	✖	✖
Use technology resources for problem solving, self-directed learning, and extended learning activities.	✖	✖	✖	✖
Determine when technology is useful and select the appropriate tools and technology resources to address a variety of tasks and problems.	✖	✖	✖	✖
Technology Problem-Solving and Decision-Making Tools				
Use technology resources for problem solving, self-directed learning, and extended learning activities.	✖	✖	✖	✖
Determine when technology is useful and select the appropriate tools and technology resources to address a variety of tasks and problems.	✖	✖	✖	✖

The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 1

Jacob has broken his foot and is eager to rejoin his friends in the tree house. The tree house detectives decide that devising a plan to get Jacob safely into the tree house will be their next case and quickly begin to research the best way to lift him. Bianca decides that this case will also be a great opportunity for her to learn more about women engineers for her career day presentation. The tree house detectives begin their investigation with Dr. D, who helps them learn about energy, force, motion, and doing work. Deciding that they have the "energy" and are willing to do the "work," the tree house detectives contemplate building an elevator. However, after visiting Otis Elevator, they realize building one is too complicated even for the tree house detectives. On the way back to the tree house, they see a ramp and determine that must be the solution. They contact a friend who is in a wheelchair to learn more about ramps and how they help people with disabilities gain access to places.

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Objectives

The students will

- understand the concepts of inertia.
- understand how the amount of force changes with the use of various simple machines.
- distinguish between potential and kinetic energy.
- understand the concept of gravity.
- use formulas to calculate work.
- learn that the Sun is the source of all energy for food chains.
- use a 12:1 ratio to construct ramps of different sizes.
- investigate various engineering careers.

Vocabulary

energy – ability to do work

force – push or pull that gives energy to an object, causing it to start moving, stop moving, or change its motion

friction – force that opposes the motion of an object

gravity – the mutual force of attraction between objects

inclined plane – slanted surface used to raise an object

inertia – tendency of objects to remain in motion or stay at rest unless acted upon by an unbalanced force

kinetic energy – energy that a moving object has due to its motion; energy of motion

potential energy – energy stored in an object due to its position

ratio – the relationship in quantity, amount, or size between two or more things

simple machine – any of various elementary devices considered as the elements of which all machines are composed and including the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw

weight – response of mass to the pull of gravity

work – product of a force applied to an object and the distance through which the force is applied; force times distance

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Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 1 of *The Case of the Powerful Pulleys*, read the program overview (p. 5) to the students. List and discuss questions and preconceptions that students may have about work, force, and energy.
2. Record a list of issues and questions that the students want answered in the program. Determine why it is important to define the problem before beginning. From this list, guide students to create a class or team list of three issues and four questions that will help them to better understand the problem. The following tools are available on the web site to assist in the process.

   Problem Board - Printable form to create student or class K-W-L chart

   Problem Based Learning (PBL) Questions - Questions for students to use while conducting research

   Problem Log - Printable log for students with the stages of the problem-solving process

   The Scientific Method - Chart that describes the scientific method process
3. Focus Questions - Questions at the beginning of each segment help students focus on a reason for viewing and can be printed ahead of time from the educator's area of the web site so students can copy them into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.
4. What's Up? Questions - Questions at the end of the segment help students predict what actions the tree house detectives should take next in the investigation process and how the information learned will affect the case. These questions can be printed from the web site ahead of time for students to copy into their science journals.

Careers

civil engineer
electrical engineer
chemist
construction worker
elevator operator
physicist

View Segment 1 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. Have students reflect on the "What's Up?" questions asked at the end of the segment.

2. Discuss the Focus Questions.

3. Students should work in groups or as a class to discuss and list what they know about work, force, and energy. Have the students brainstorm ideas on how to best get Jacob into the tree house. As a class, reach a consensus about what additional information they need to know before they can determine how to best lift Jacob into the tree house. Have the students conduct independent research or provide students with the information needed.

4. Have the students complete Action Plans, which can be printed from the web site, and then conduct independent or group research by using books and internet sites noted in the Research Rack section of the NASA SCI Files™ web site. Educators can also search for resources by topic, episode, and media type under the Educator's main menu option *Resources*.

5. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. The variety of activities is designed to enrich and enhance your curriculum. Activities may also be used to help students "solve" the problem along with the tree house detectives.

6. Have the students work individually, in pairs or in small groups, on the Problem-Based Learning (PBL) activity on the NASA SCI Files™ web site.

• To begin the PBL activity, read the scenario to the students.

- Read and discuss the various roles involved in the investigation.
- Print the criteria for the investigation and distribute.
- Have students use the Research Rack located on the web site and the online tools that are available.

7. Having students reflect in their journals what they have learned from this segment and from their own experimentation and research is one way to assess the students. In the beginning, students may have difficulty reflecting. To help students, give them specific questions to reflect upon that are related to the concepts.

8. Have students complete a Reflection Journal, which can found in the Problem-Solving Tool section of the online PBL investigation or in the Instructional Tools section of the Educator's area.

9. The NASA SCI Files™ web site provides educators with general and specific evaluation tools for cooperative learning, scientific investigation, and the problem-solving process.

Resources (additional resources located on web site)

Books

Cole, Joanna: *Magic School Bus "Plays Ball" -A Book About Forces.* Scholastic Inc., 1997, ISBN: 05909222408.

Dahl, Michael: *Inclined Planes.* Bridgestone Books, 1996, ISBN: 1560654473.

Dunn, Andrew: *Simple Slopes.* Thomas Learning, 1993, ISBN: 1568470177.

Hacker, Carlotta: *Scientists.* Crabtree Publishing Co., 1998, ISBN: 0778700062.

Lafferty, Peter: *Eyewitness Books: Force and Motion.* Darling Kindersley, 1999, ISBN: 0789448823.

Yount, Lisa: *Twentieth Century Women Scientists.* Facts on File, Inc., 1996, ISBN: 0816031738.

Web Sites

The Society of Women Engineers
Students and educators can visit the web site to learn more about engineering careers, scholarship programs, and more.
http://swe.org

Kinetic and Potential Energy
Visit this web site to learn why amusement parks are great places to study potential and kinetic energy.
http://library.thinkquest.org/2745/data/ke.htm?tqskip1=1&tqtime=0710

Potential and Kinetic Energy
An interactive web site that explains the difference between potential and kinetic energy.
http://www.usoe.k12.ut.us/curr/science/sciber00/8th/forces/sciber/potkin.htm

Energy: Grade 4
A fourth grade explanation of different types of energy.
http://www.nyu.edu/pages/mathmol/textbook/energy.html

Gravity
Fourteen questions answered about gravity.
http://spaceprojects.arc.nasa.gov/Space_Projects/SSBRP/gravity.html

Roadmaps & Rampways
Profiles of students with disabilities pursuing careers in mathematics, science, engineering, and technology. Heartwarming and inspiring stories.
http://www.entrypoint.org/rr/index.html

Activities and Worksheets

In the Guide

Inert Inertia
Learn all about Newton's inertia 16

Forcing the Issue of Force
Compare the force needed to lift a weight using various simple machines. 17

Stop in the Name of Energy!
Learn the difference between kinetic and potential energy 18

Wait, Weight Doesn't Matter?
Experiment to find out how gravity and air resistance work on Earth 20

Newton Has the Joules
Discover what a Newton is and how it relates to a joule 21

Going Up Anyone?
Learn what a ratio is and how they are used to build ramps 22

Answer Key
..... 23

On the Web

Where DOES My Energy Come From?
Learn how the Sun provides all the energy you need

So What Do You Want To Be When You Grow Up?
Research various careers in mathematics, science, and technology

Inert Inertia

Purpose

To understand the basic concept of inertia

Materials

1-m wooden board
various assortment of books
medium-sized toy car
1 large washer
meter stick
science journal

Background

Sir Isaac Newton was an English physicist and mathematician who studied the properties of force and motion. He developed three laws of motion known as Newton's Laws. Newton's First Law of Motion states that an object at rest will remain at rest, and an object in motion will remain in motion at a constant velocity unless an unbalanced force acts upon it. This tendency of objects to either remain at rest or in motion is called inertia.

Procedure

1. Stack two or three books on a flat surface and place one end of the board on top of the books to create a ramp so that one end is approximately 10 cm from the surface.
2. Measure the height of the ramp and record in data chart.
3. Use a thick book, like a dictionary, to form a wall at the bottom of the ramp. See diagram 1.
4. Place the large washer on top of the car.
5. Put the car at the top of the ramp and release it, making sure that you do not push the car.
6. After the car hits the wall, measure the distance from the car to where the washer landed and record this distance in the data chart.
7. Repeat steps 4-6 for two additional trials.
8. Raise the ramp an additional 5 cm and record height in data chart.
9. Repeat steps 4-7.
10. Repeat steps 8-9 by raising the ramp again.
11. Find the average distance (cm) that the washer traveled at each height.
12. Discuss your findings and conclusions.

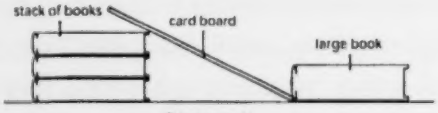

Diagram 1

Data Chart

WASHER WILL TRAVEL				
Height of Ramp (cm)	Distance Trial 1 (cm)	Distance Trial 2 (cm)	Distance Trial 3 (cm)	Average Distance (cm)

Conclusion

1. Describe what happened to the washer when the car hit the wall.
2. Why do you think it happened?
3. Explain the relationship between the height of the ramp and the distance the washer traveled.
4. What is the relationship between inertia and the speed of the car at the bottom of the ramp?
5. Define inertia in your own words.
6. Explain how Jacob unfortunately encounters inertia on his scooter.
7. Using what you now know about inertia, explain why it is necessary to wear seat belts in a vehicle.

Extension

If the heights of the ramps were the same for all groups, have students share their data as a class and find a class average for each trial. Create a graph showing the relationship between the height of the ramp and the distance the washer traveled. Use washers of different weights and repeat experiment.

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Forcing the Issue of Force

Purpose

To understand that force is needed to do work

Materials (per group)

1 pulley
hook setup for pulley
1 inclined plane (40 cm)
1 rope
1 2.1 kg weight with hook
1 spring scale
meter stick
calculator (optional)
science journals

Procedure

1. In your science journal, define work.
2. Discuss your definition with your group and reach a consensus.
3. Discuss lifting the weight, using an inclined plane, a pulley, and rope.
4. Predict which way of lifting the weight will require the most force and record in data chart.
5. Loop one end of the rope through the hook of the weight and tie a knot to secure the weight to the rope.
6. Loop the other end of the rope through the spring scale hook and secure with a knot. See diagram 1.
7. Hold the spring scale in one hand until the rope is taut and the weight is resting on the floor. The spring scale should read "0."
8. Have your partner hold the meter stick with one end on the floor next to the rope and weight. Slowly lift the weight 30 cm from the surface.
9. Read the spring scale and record the amount of force in data chart.
10. Place the weight at the bottom of the inclined plane and place the meter stick along the side of the inclined plane.
11. Holding the spring scale in one hand, slowly pull the weight 30 cm up the inclined plane.
12. Read the spring scale and record the force.
13. Untie the spring scale from the rope and loop the rope through the pulley.
14. Reattach the spring scale to the rope.
15. Hang the pulley from the hook designated by your teacher. See diagram 2.
16. Place the meter stick so that you can measure the distance to lift the weight.
17. Hold the spring scale in one hand and slowly pull down, lifting the weight 30 cm. Record the force.
18. Compare the amount of force needed for each test and discuss the results.

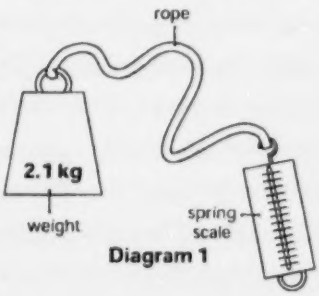

Diagram 1

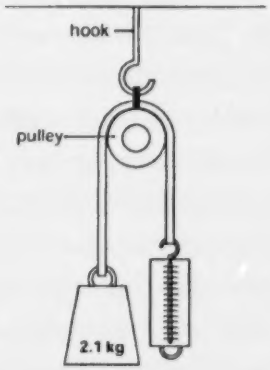

Diagram 2

Conclusion

1. How did the force that was needed to lift the weight compare with the rope, the inclined plane, and the pulley?
2. Was your prediction correct? Why or why not?
3. Which simple machine do you think the tree house detectives should use to get Jacob into the tree house? Why?
4. Why do people use simple machines?
5. How can you use this information to help solve problems in your daily life?

	Force	Distance
Rope Only		
Inclined Plane		
Pulley		

Stop in the Name of Energy!

Purpose

To understand the difference between kinetic and potential energy
To understand friction

Materials

small amounts of vegetable oil, water, salt, and butter
2 small eyedroppers
waxed paper
cardboard (40 cm x 30 cm)
5 checkers
tape
scissors
books
metric ruler
paper towel
science journal

Procedure

1. In your science journal, write definitions for potential energy, kinetic energy, and friction.
2. Discuss your definitions with your group and reach a consensus for each term.
3. Measure and cut five strips of waxed paper 30 cm x 4 cm.
4. Tape the top of each strip of waxed paper onto the cardboard, leaving space between each strip. Label each strip A, B, C, D, and E. See diagram 1.

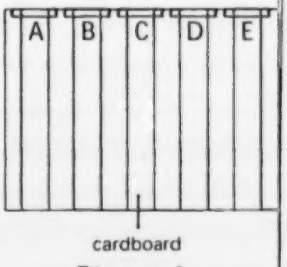

Diagram 1

5. Stack several books and place a large piece of waxed paper on the table in front of the books. This piece will be used for any drips that might occur.
6. Lean the cardboard against the stack so that the cardboard is slanted away from the books and the bottom edge is on the waxed paper. See diagram 2.

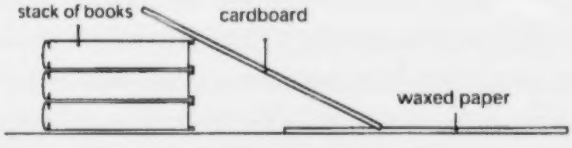

Diagram 2

7. Strip A will be the control strip.
8. Using an eyedropper, place five drops of water on strip B.
9. On strip C, place five drops of water and then sprinkle a pinch of salt on top of the water.
10. Using a paper towel or napkin, smear a small amount of butter on strip D.
11. Using the other eyedropper, place five drops of vegetable oil on strip E.
12. Place a checker on the top of strip A. What type of energy does the checker have?
13. Let go of the checker and observe the distance that the checker moved down the waxed paper. What type of energy did the checker have as it moved?
14. Measure the distance and record in the data table below.
15. Repeat steps 11-13 for two more trials.
16. Repeat steps 11-14 for each additional strip.
17. Calculate the average distance each checker moved for each strip.
18. Discuss your findings and compare strips 2-5 to the first strip (control).
19. Discuss your definition of potential energy and kinetic energy and decide whether your definitions were correct.
20. Discuss friction and how it differed for each strip.

Stop in the Name of Energy!

Data Table

Strip	Trial 1	Trial 2	Trial 3	Average
A				
B				
C				
D				
E				

Questions

1. Describe how the checker received its potential energy.

2. What happened as the checker moved down the strips?

3. Why did the checker move farther on some strips in relation to others?

4. Why do we strive to overcome friction?

5. How can you apply today's learning to another part of your life?

Extension

Use a penny as a weight for each checker. Predict whether the outcomes will be different. Repeat trials and compare. Continue to add more pennies to vary the weight and compare results.

Wait, Weight Doesn't Matter?

Purpose

To learn that gravity pulls all objects towards the center of the Earth
To learn that air resistance can change the speed in which objects will fall

Materials

4 coins
thick paper
metric ruler
scissors
pencil
science journal

Procedure

1. Take a coin and trace it onto the paper.
2. Cut out the circle, making sure that the paper circle is not bigger than the coin.
3. Predict what will happen if you drop the coin from one hand and the paper coin from the other. Record your prediction in your science journal.
4. Place the coin in one hand and the paper coin in the other. Drop them both at the same time. Record your results.
5. To further enforce the idea that all objects are going to drop at the same rate, try the next activity.
6. Stack 3 coins on top of each other and tape together.
7. Place one coin on the edge of the table and place the stack of coins on the edge also, but 5 cm apart from the single coin.
8. Place a ruler behind the coins so that the ruler is touching them.
9. Make a prediction as to what is going to happen when you push the ruler and make the coins fall off the table.
10. Using the ruler, push the coins off the table at the same time. Observe and record your observations in your science journal.
11. Discuss your results with your team partner and class.

Conclusion

1. When the coin and paper coin were dropped separately, what happened and why?
2. In the experiment with the single coin and stack of coins, what happened and why?
3. If gravity is always pulling you down, how does it help you?
4. How would life be different if we had less gravity or no gravity at all?
5. Would a bowling ball and a pebble fall at the same speed and hit the ground at the same time if dropped from a high building?
6. NASA astronauts on the Moon dropped a feather and a hammer. Which one do you think hit the moon surface first and why?

Extension

Research terminal velocity to find out more about how gravity affects objects as they fall.

Newton Has the Joules

Purpose: To calculate work in a variety of tasks

Formulas/conversions:

Work = Force x Distance (W = F x d)
lb = 2.21 kg
1 kg = 9.8 newtons
1 newton-meter = 1 joule

Materials

scales or balance
objects to lift
meter sticks
calculators
science journal

Background

Work is done by a force acting through a distance. For work to be done, a force must move an object. If there is not movement, there is no work. Work is the product of the force applied to an object and the distance through which the force is applied. The formula used to express this concept is work (W) = force (F) x distance (d). As you can see from the formula, two conditions must be met for work to be done. One, a force must be applied, and two, the force must make the object move.
To calculate how much work is being done, follow these steps:

1. Find the mass of the object in grams and convert to kilograms.
2. Convert the mass of the object to weight by multiplying the mass by 9.8. Force is measured in newtons, so this number is the amount of force or the number of newtons that it will take to lift the object.
3. Measure (in meters) the distance that the object is lifted. Remember that the force must be applied in the same direction. If you lift an object 2 meters and walk 5 meters with it, you only did work when you lifted the object.
4. Multiply the number of newtons and the distance the object was lifted to get the unit of work, which is called a newton-meter (N-m).
5. One newton-meter is equal to one joule (unit of measure for energy or work).

Procedure

1. Your group will be competing with the other groups in your class. The object of the game is to do more work than any other group.
2. You have 10 minutes to carefully read the explanation above and discuss within your group how work is done. Reach a consensus about how to do more work than the other groups.
3. Choose one person in your group to be the worker.
4. Choose three objects in the classroom for the worker to lift and record them in your science journal.
5. Using the balance, find the mass of the first object and convert to newtons.
6. Have the worker lift the object. Measure and record the distance the object was lifted.
7. Multiply the newtons and the distance to find Newton-meter (unit of work).
8. Convert newton-meters to joules and record in your science journal.
9. Repeat steps 3-8 with the other two objects.
10. Find the sum of the three joules of work completed by your group.
11. Share with the class the amount of work your group did to determine which group did the most work. They are the "hardest workers."

Conclusion

1. What is force?
2. What is work?
3. Since Jacob weighs 90 lb and they need to lift him over 3.5 m, how much work will they need to do to lift him to the tree house?
4. What other factors do the tree house detectives have to consider to calculate the amount of work needed to get Jacob into the tree house?

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Going Up Anyone?

Problem

To learn about ratios while developing a ramp

Background

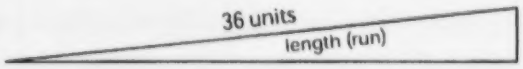
A ratio is the quotient of two numbers or mathematical expressions. For example, the ratio of 6 to 3 may be expressed as 6:3, 6/3, and 2 to 1. A ratio is used to show a relationship in quantity, amount, or size between two or more things.

Procedure

1. Discuss ratios. In your science journal, list various ratios that you may have encountered in everyday life.
2. In Segment 1, Bianca suggested that the tree house detectives check out ramps as a possible solution to the problem. A handicap ramp must be built by using a ratio of 12 to 1 (12:1), which means that for 1 unit of height (rise) you need 12 units of length (run).

Materials

large piece of cardboard
books or bricks
tape measure or meter stick
pencil
scissors
science journal



3. Discuss in your group any ramps that you may have seen. If possible, walk around your school to look at any handicap ramps that may be found. Measure the rise versus the run and record in your science journal.
4. Using bricks or books, construct a platform 1 to 12 cm high that will be the platform for the top of your ramp.
5. Measure the actual height or rise of the platform in cm and record in your science journal.
6. Multiply the height by 12 to determine the length (run) of the ramp.
7. Using cardboard, measure and construct your ramp.
8. Share what you have constructed and explain the math you used to determine the length (run) of each ramp.
9. If you were able to measure the rise and run on any ramps on the school grounds, calculate to find whether they meet the 12:1 ratio.
10. Jacob will have to be lifted 3.5 m. Using a 12:1 ratio, how long will the ramp need to be?

Conclusion

1. Why is it important to have a ramp ratio of 12:1 for handicapped people?
2. How can you determine how much length you need for a ramp if you know the height?
3. How would you determine the height of a ramp if you were only given the length?
4. Is the length of the ramp needed to lift Jacob reasonable? Why or why not?
5. Do you think the tree house detectives are going to build a ramp?

Answer Key

Inert Inertia

1. The washer continues to move in a forward motion.
2. Both the toy car and the washer were put into motion because of the ramp (force of gravity). According to Newton's First Law, objects that are in motion stay in motion. However, the car was acted upon by another force, the book wall, and therefore stopped. The washer was also in motion and continued its motion because it was not attached to the car.

3-4. The higher the ramp, the faster the car would move and the farther the washer would travel after the car struck the wall.

5. Answers may vary.
6. Jacob's scooter stops when it hits the curb, but he continues to move and flies through the air.
7. Answer will vary.

Forcing the Force

1. The students should have discovered that the inclined plane required less force to lift the weight. The pulley only used one string and that is the same as lifting the weight without a pulley. If additional pulleys and strings are used then the force would reduce.
2. Answers will vary.
3. Answers will vary. Students will probably say the inclined plane because this experiment concluded that the inclined plane took less force to lift the weight.
4. Answers will vary but should include that simple machines make "work" easier.
5. Answers will vary.

Stop in the Name of Energy!

1. The checker received its potential energy from the person placing it at the top of each strip.
2. Answers will vary.
3. The amount of friction was stronger on some strips.
4. We strive to overcome friction so machines can become more efficient.
5. Answers will vary, but should include answers such as oil for engines, bike gears, driving on wet roads, and so on.

Wait, Weight Doesn't Matter?

1. The coin hit the floor before the paper coin. As the paper coin fell, air resistance opposed its downward motion, so it moved more slowly.
2. The single coin hit the floor at the same time as the stack of three coins. Even though the stack of coins was heavier, it did not hit the floor first because the single coin had enough weight to overcome the small amount of air resistance.
3. Gravity is the force that keeps you and other objects on the ground. If it weren't for gravity, we would have a difficult time staying in one place!
4. If there were less gravity, we would weigh less and be able to jump higher. Depending on how much gravity there was, we might even need to be weighted down so as not to float away. If there were not any gravity, we would float around like astronauts do in space.
5. Regardless of their masses, objects accelerate at the same rate. The acceleration of a falling object is due to the force of gravity between the object and the Earth. So if a pebble and a bowling ball were dropped at the same time from the same height, they would hit the ground at the same time.
6. When the astronauts dropped the feather and the hammer on the Moon, they proved that Galileo was correct in his description of the motion of falling objects. The feather and the hammer hit the surface of the Moon at the same time. They accelerated at the same speed, and because there is no air on the Moon, there was no air resistance to slow the feather down as on Earth.

Newton Has the Joules

1. Force is a push or a pull applied to an object.
2. Work is done when you apply a force to an object over a distance.
3. 1,396 joules. To find Jacob's mass, divide 90 pounds by 2.21 to get 40.7 kilograms. Multiply 40.7 kilograms by 9.8 newtons to get 398.9 newtons. Multiply 398.9 newtons by 3.5 meters to get 1,396 newton-meters. Convert newton-meters to joules.
4. The tree house detectives must also consider friction and the weight of the rope and any other materials used to lift Jacob up into the tree house.

Going Up Anyone?

1. Handicap ramps need a ratio of 12:1 to make it easier for people to walk or push a wheelchair up the ramp. If the ramp were too steep, it would be too difficult.
2. To determine the length of a ramp, multiply the height by 12.
3. To determine the height of a ramp, divide the length by 12.
4. Students should conclude that the ramp would need to be 42 meters long, much too long, since most yards are not that big.
5. Answers will vary, but most should determine that the tree house detectives will not build the ramp.

On the Web

Where DOES My Energy Come From?

1. The energy for all food webs begins with the Sun.
2. Energy is gathered into one organism and transferred to others as they are eaten.
3. To get energy to our body, we need to eat and drink.

The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 2

The tree house detectives continue to search for a way to lift Jacob into the tree house. Dr. D asks them to meet him at the circus to learn more about simple machines. They are not quite sure what a circus has to do with simple machines, but they know if Dr. D is there, it will be fun. After the circus, they decide that pulleys might be helpful in lifting Jacob. They discover on the Internet that NASA uses pulleys to lift the Space Shuttle onto the back of an airplane. To learn more about pulleys, they dial up Ms. Ennix, an aerospace engineer at NASA Dryden Space Flight Center in California. The tree house detectives feel that this is definitely the way to go but think they need to do a little more research. They visit Ms. Lisa Jones, an aerospace engineer at NASA Langley Research Center in Hampton, VA who uses pulleys to lift airplanes for crash tests at the gantry. Now they are certain that pulleys are the answer, but there are just a few little problems to overcome.

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Objectives

The students will

- understand the principle of the Archimedes Screw.
- convert US customary units (feet) to metric (meters).
- understand and use simple machines.
- understand how simple machines change the direction of the force.
- learn how to combine simple machines to create compound machines.

Vocabulary

fulcrum – fixed point at which a lever pivots

gantry – a platform made to carry a traveling crane and supported by towers running on parallel tracks

lever – a bar that is free to pivot, or move about, a fixed point when an effort force is applied

load – something taken up and carried

load distance – the distance the load is moved

pulley – a small wheel with a grooved rim used with a rope or chain to change the direction of a pulling force and in combination to increase the force applied for lifting

screw – inclined plane wrapped around a cylinder to form a spiral

wedge – inclined plane that moves

wheel and axle – a simple machine consisting of a grooved wheel turned by a cord or chain with a firmly attached axle (as for winding up a weight) together with supports

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 2 of *The Case of the Powerful Pulleys*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 1 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 1. Use tools located on the Web, as was previously mentioned in Segment 1.
4. Focus Questions–Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.
5. What's Up? Questions–Questions at the end of the segment help students predict what actions the tree house detectives should take next in the investigation process and how the information learned will affect the case. These questions can be printed from the web site ahead of time for students to copy into their science journals.

View Segment 2 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the

Focus Question icon appears to allow students time to answer the question.

After Viewing

1. Have students reflect on the "What's Up?" questions asked at the end of the segment.
2. Discuss the Focus Questions.
3. Have students work in small groups or as a class to discuss and list what new information they have learned about force, energy, motion, work, and simple machines. Organize the information and determine whether any of the students' questions from Segment 1 were answered.
4. Decide what additional information is needed for the tree house detectives to determine the best way to get Jacob into the tree house. Have students conduct independent research or provide students with information as needed. Visit the NASA SCI™ Files web site for an additional list of resources for both students and educators.
5. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
6. If time did not permit you to begin the web activity at the conclusion of Segment 1, refer to number 6 under "After Viewing" on page 13 and begin the Problem-Based Learning activity on the NASA SCI™ Files web site. If the web activity was begun, monitor students as they research within their selected roles, review criteria as needed, and encourage the use of the following portions of the online, Problem-Based Learning activity:

   Research Rack - books, internet sites, and research tools

   Problem-Solving Tools - tools and strategies to help guide the problem-solving process

   Dr. D's Lab - interactive activities and simulations

   Media Zone - interviews with experts from this segment

   - listing of Ask-An-Expert sites and biographies of experts featured in the broadcast

7. Have students write in their journals what they have learned from this segment and from their own experimentation and research. If needed, give students specific questions to reflect upon as suggested on the PBL Facilitator Prompting Questions instructional tool found in the educator's area of the web site.
8. Continue to assess the students' learning, as appropiate, by using their journal writings, problem logs, scientific investigation logs, and other tools that can be found on the web site. Visit the Research Rack in the tree house, the online PBL investigation main menu section "Problem-Solving Tools," and the "Tools" section of the educator's area for more assessment ideas and tools.

Careers

aerospace engineer
circus performer
acrobat
space shuttle commander
pilot

Resources

Books

Hodge, Deborah: *Simple Machines.* Kids' Corner Press LTD, 1998, ISBN: 1550743112.

Richards, Jon: *Work and Simple Machines.* Cooper Beech Books, 2000, ISBN: 0761311599.

Riley, Peter D.: *Forces and Motion.* Heinemann Library, 2000, ISBN: 1575727722.

VanCleave, Janice Pratt: *Janice VanCleave's Machines.* Wiley, 1993, ISBN: 0471571083.

Whittle, Fran: *Simple Machines.* Raintree Steck-Vaughn, 1998, ISBN: 0817248900.

Web Sites

The Topic: Simple Machines
Looking for background information about simple machines? This site has it all. There are also six different activities you can complete to learn more about simple machines.
http://www.eduscapes.com/42explore/smplmac.htm

Simple Machines
Get a quick description of all six simple machines as well as great pictures. Each simple machine also has a link for more information.
http://sln.fi.edu/qa97/spotlight3/spotlight3.html

How Many? A Dictionary of Units of Measure
This site is an on-line dictionary for all units of measure from A-Z.
http://www.unc.edu/~rowlett/units/index.html

4000 Years of Women in Science
Women are, and always have been, scientists. This site lists over 125 names from our scientific and technical past. Biographies, references, and photographs are included on this site.
http://www.astr.ua.edu/4000WS/4000WS.html

Activities and Worksheets

In the Guide **Popcorn, Get Your Popcorn Up Here!**
Investigate the principle behind Archimedes Screw while enjoying popcorn 29

Sizing It Up
Help Mike and Dan with their science project while learning to convert from US customary units to metric units of measurement 30

Keeping It Simple–Six Simple Machines
Rotate through stations to learn about the six different simple machines 31
Data Chart 1 34
Data Chart 2 35

Mission Possible
As a member of a rescue team, you must get supplies to the other side by changing the direction of the force. 36

Answer Key
..... 37

On the Web **Simply Compounding**
Conduct an internet search for simple machines and learn how to combine them to create a compound machine

Popcorn, Get Your Popcorn Up Here!

Problem To learn the principle of Archimedes' Screw

Background One of the first people to use a screw to lift was the ancient Greek scientist Archimedes. He invented a screw pump that could raise water from a lower level up to a higher level, making it flow against the force of gravity. Even though Archimedean screws were first built more than two thousand years ago, they are still used today. African farmers use them to irrigate their crops by lifting the water from the river into raised irrigation canals. The pumps are usually powered either by animals or by hand.

Teacher Prep Cut the bottom off each bottle. Near the top of each bottle, cut a triangular hole. See diagram 1

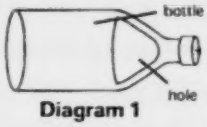

Diagram 1

Procedure

1. Measure the diameter of the 2-liter bottle.
2. Using the compass, measure and draw seven circles that are 2 mm smaller than the diameter of the bottle. Mark the center of each circle.
3. Using scissors, carefully cut out each circle.
4. Using the ruler, draw a line from the center of the circle to the edge (radius).
5. Cut from the edge to the center, being careful not to cut through the middle point.
6. Separate the edges of the cut and use a hole punch to make a hole at the center mark of the circle. See diagram 2.
7. To join the circles, place two circles on top of each other so that the slits line up. Glue the right edge of the slit on the bottom circle to the slit that is on the left edge of the top circle.
8. Continue this pattern until all seven have been joined to create the screw.
9. Slide the dowel through the holes of all seven circles.
10. Stretch the circles along the dowel.
11. Glue the slits at the top and the bottom of the screw firmly to the dowel. See diagram 3.
12. Push a small tack through the cap of the bottle. It may be necessary to use a hammer.
13. Screw the cap onto the bottle.
14. Place the completed screw into the bottle.
15. To hold the screw in place, press the end of the dowel firmly into the tack. It may be necessary to use a hammer to tap it into place. See diagram 4.
16. Place the bowls at two different elevations.
17. Put the popcorn in the lower bowl.
18. Place the end of the screw that has the cap into the bowl of popcorn.
19. Begin to twist the dowel and watch the popcorn as it rises up to the top of the pop bottle. When it reaches the top it should fall into the bowl that you placed at a higher elevation. See diagram 5.
20. Enjoy the popcorn.

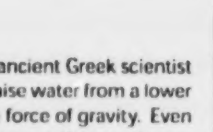

Diagram 2

Materials

one 1/4" wooden dowel
glue
2 empty two-liter bottles with caps
tag board
scissors
compass
small tack
popped popcorn
metric ruler
hole punch
hammer
two bowls

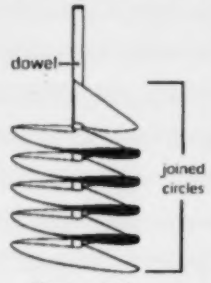

Diagram 3

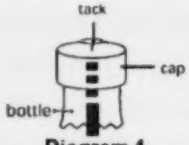

Diagram 4

Conclusion

1. Explain how the screw raised the popcorn.
2. Why would this type of device be used today?
3. Research Archimedes and write a brief paragraph about his life.

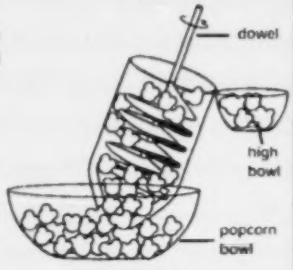

Diagram 5

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Sizing It Up

Problem

To learn how to convert customary units of measurement to SI/Metric units

Materials

yardsticks
meter sticks
inch/centimeter rulers
quart container
liter container
1 lb weight
1 kg weight
conversion chart
science journal

Procedure

Two students, Mike and Dan, have created a very large science fair project. They need to solve several problems.

- First, they are concerned that the project is not going to fit through the door. They have measured the doorway and found that it is 84 inches high and 48 inches wide. When they measured the project, which happens to be a rectangular prism, it was 180 centimeters tall, 90 centimeters wide, and 1 meter deep.
- Second, they need 5 liters of water to go with their project and all they have are quart containers.
- Third, the table where they are to display their project will only hold 25 pounds. Their project is 15 kilograms. Will they need a different table?

1. Compare and contrast an inch and a centimeter. Record your observations in your science journal.
2. Compare and contrast a meter stick to a yardstick? Record your observations in your science journal.
3. Look at the conversion chart and discuss with your group how to solve the first problem.
4. Solve the problem and record the answer in your science journal.
5. Compare and contrast quarts and liters. Record your observations in your science journal.
6. Discuss how to solve the second problem and record answer in journal.
7. Compare and contrast pounds and kilograms. Record your observations in your science journal.
8. Discuss how to solve the third problem and record answer in journal.
9. Discuss with your group what Mike and Dan should do to have a successful science fair experience. Write your conclusions in your science journal.

When you want to convert:	Multiply by:	To find:
Length		
inches (in)	2.54	centimeters
centimeters (cm)	0.39	inches
feet (ft)	0.30	meters
meters (m)	3.28	feet
yards (yd)	0.91	meters
meters (m)	1.09	yards
miles (mi)	1.61	kilometers
kilometers (km)	0.62	miles (mi)
Mass and Weight*		
ounces (oz)	28.35	grams
grams (g)	0.04	ounces
pounds (lb)	0.04	kilograms
kilograms (kg)	2.2	pounds
Volume		
liters (L)	1.06	quarts (qt)
liters	0.26	gallons
gallons (gal)	3.78	liters

*Weight as measured in standard Earth gravity
**Abbreviations are in parentheses.

Conclusion

1. When would you use conversion charts in your daily life?
2. Why would the tree house detectives have to convert some of their measurements?

Extension

Students should be given an opportunity to create problems similar to the ones above and share them with the class to solve. Create problems using volume, temperature, and area.

Keeping It Simple–Six Simple Machines

Problem To explore and use simple machines to understand how they make "work" easier

Teacher Note This activity is divided into six stations where six small groups will rotate through each station to explore and use simple machines. This exploration may be completed over 2-3 days. To set-up the activity:

1. Gather and set up materials for each station as listed.
2. Number the stations.
3. Copy student procedure directions for each station and place on appropriate table.
4. Divide students into six groups and pass out Simple Machines Data charts 1 and 2 (pp. 34 and 35).
5. Assign each group a station and explain how to rotate through the stations. Station 1 will move to Station 2, and so on.
6. It may be helpful to set a timer so that students will all rotate at the same time.
7. At the end of the activity, discuss the questions and the various simple machines.

1) Inclined Plane

Problem Which ramp will make moving a large piece of furniture the easiest?

Procedure

1. Attach the spring scale to the string around the paperback books.
2. Lift the books with the spring scale.
3. Read and record on the data sheet the number of grams it took to lift the books.
4. Use the wooden plank or cardboard and the protractor to construct a ramp that has a 60-degree angle. Put one end of the inclined plane on a stack of books. Pull the books up the inclined plane, keeping the spring scale parallel to the ramp.
5. Read and record in the Data Chart 1 (p. 34) the number of grams needed to move the books up the ramp.
6. Repeat steps 4-5 using a 30-degree inclined plane

Ramp with 60-degree angle

Materials

Inclined Plane

- wooden plank or sturdy piece of cardboard
- stack of books
- protractor
- 2 paperback books tied together with string
- spring scale

Questions

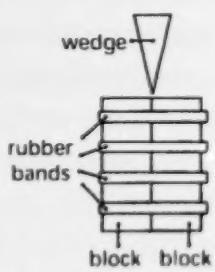
1. Did the ramp make the work easier?
2. Which ramp made the work easiest? Why?
3. What happened to the length of the inclined plane as the angle became smaller?
4. How can you use an inclined plane to help you in everyday life?

2) Wedge

Problem How can a wedge help separate two objects?

Procedure

1. Use the rubber bands to band the two same sized blocks of wood together. If you can easily pull them apart, add more rubber bands.
2. Use the smaller third block of wood to pry the banded blocks apart. Record your observations in Data Chart 1.
3. Use the wedge to pry apart the banded blocks. Record your observations in Data Chart 1.



Materials

Wedge

- blocks of wood the same size
- one smaller block
- rubber bands
- wedge of wood

Questions

1. What happened when you tried to separate the banded blocks with the smaller block of wood?
2. Compare what happened when you used the block and then the wedge to separate the banded blocks? Explain why there was a difference.
3. How can you use a wedge to help you in everyday life?

Keeping It Simple (continued) Six Simple Machines

3) Wheel and Axle

Problem

Does a larger handle on a screwdriver make work easier?

Procedure

1. Observe the screwdrivers and determine which part of the screwdriver is the wheel and which part is the axle. Discuss and record in Data Chart 1 (p. 34).
2. First, use the screwdriver with the smaller handle. Turn the screwdriver until about half the screw is inserted into the wood. Observe and rate the amount of force needed to turn the screw into the wood.
3. Use the second screwdriver to finish inserting the screw into the wood. Observe and rate the amount of force used. Record.
4. Compare the amount of force used in steps 2 and 3.

Questions

1. Which screwdriver made it easier to insert the screw into the wood?
2. Explain you answer.
3. How can you use a wheel and axle in everyday life?

Materials

Wheel and Axle

two screwdrivers that are the same length but have different sized handles
piece of wood
6 screws (1 for each group)

4) Screw

Problem

To understand that the pitch of a screw determines the difficulty of turning the screw

Procedure

Each group should use a new set of predrilled holes.

1. Observe each screw and nail and note any differences in Data Chart 2 (p. 35).
2. Place screw A in one of the predrilled holes.
3. Use the line drawn on top of the screw to count the number of turns it takes using the screwdriver to insert the screw entirely into the block of wood.
4. Record the number of turns in your data chart. Observe the amount of force used and record.
5. Repeat steps 2-4 with screw B.
6. Using just your hands, try to insert the nail into the wood. Use the line drawn on top of the nail to help you count the number of turns.
7. Record the number of turns and your observations in the data chart.
8. Compare and contrast inserting the nail, Screw A, and Screw B.

Questions

1. How did the nail work in relation to the two screws?
2. Did you find one screw works better than the other?
3. What was the difference between the screws?
4. Which one needed more turns? Why?
5. How can screws make a difference in everyday life?

Materials

Screw

block of soft wood with 12 predrilled holes
6 nails (1 for each group)
6 sets of 2 wood screws with different pitch but equal length (pitch is the distance between the treads or ridges)
1. use permanent marker and draw a line across the top of each screw and nail
2. use tape to label screws A (larger pitch) and B (smaller pitch)

screwdriver
goggles

BEST COPY AVAILABLE 31

Keeping It Simple (concluded) Six Simple Machines

5) Lever

Problem

How does moving the fulcrum affect the amount of force needed in a lever system?

Materials

Lever
30-cm ruler
dictionary
small object such as a pencil or base 10 block for fulcrum
spring scale

Procedure

1. Place the dictionary 26 cm from the edge of the table.
2. Place one end of the ruler under the dictionary so that the 1-cm mark is covered.
3. Place the fulcrum under the ruler at the 24 cm mark.
4. Attach the spring scale to the ruler so that it is hanging downward. Gently pull on the spring scale until you just begin to lift the dictionary. See diagram 1.
5. Read and record in Data Chart 2 (p. 35) the number of grams used.
6. Keeping the 1-cm side of the ruler underneath the dictionary, move the fulcrum to the 15-cm mark. Repeat steps 4-5.
7. Repeat step 6, using 6 cm as the fulcrum's position.

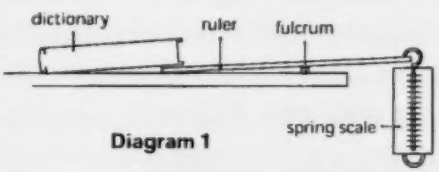


Diagram 1

Questions

1. Did the number of grams used to lift the dictionary change when you moved the fulcrum? How?
2. If you wanted to lift a heavy load, where should you place the fulcrum?
3. How can you use levers to help you in everyday life?

6) Pulley

Problem

How do pulleys make work easier?

Materials

Pulley
two single pulleys
ring stand
500 g weight
80 cm of string
spring scale

Procedure

1. Use the spring scale to lift the weight off the floor or desk. Read and record the number of grams.
2. Attach the pulley to the ring stand.
3. Attach one end of the string to the weight.
4. Loop the other end through the pulley and attach the spring scale to the end of the string. See diagram 1.
5. Pull down on the spring scale to measure how many grams are needed to lift the weight and record in Data Chart 2 (p. 35).
6. Using a second pulley, construct the pulley system below. See diagram 2.
7. Pull up on the spring scale to lift the weight. Read and record grams in the data chart.

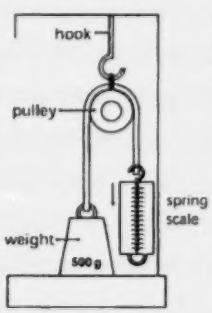


Diagram 1

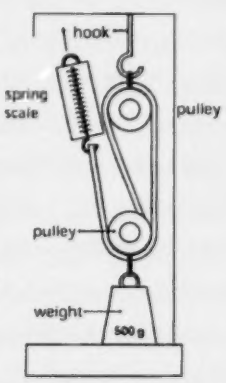


Diagram 2

Questions

1. Was there a difference between not using a pulley and using one pulley?
2. What was the difference between using one pulley and using two pulleys?
3. Why would anyone want to use just one pulley?
4. How can pulleys help you in everyday life?

Keeping It Simple Data Chart 1

Inclined Plane

Inclination in degrees	Grams
0 °	
30 °	
60 °	

Questions:

1. _____

2. _____

3. _____

Wedge

Object	Rate Observed Force
Small block	
Wedge	

Questions:

1. _____

_____

2. _____

_____

3. _____

_____

Wheel and Axle

On a screwdriver, the wheel is the _____ and the axle is the _____.

Screwdriver	Rate the Observed Force
Small-handled screwdriver	
Large-handled screwdriver	

Questions:

1. _____

_____

2. _____

_____

3. _____

_____

Keeping It Simple Data Chart 2

Screw

Observations (compare and contrast nail, screw A, and Screw B).

Screw	Number of Turns	Rate Observed Force
Nail		
Screw A		
Screw B		

Compare and contrast the insertion of screws A and B and the nail.

Questions:

1. _____
2. _____
3. _____
4. _____
5. _____

Lever

Position of Fulcrum	Grams
24 cm	
15 cm	
6 cm	

Questions:

1. _____
2. _____
3. _____

Pulley

Number of Pulleys	Grams
0	
1	
2	

Questions:

1. _____
2. _____
3. _____
4. _____

Mission Possible

Problem

To understand that simple machines can change the direction of a force

Scenario

You are part of a rescue team that needs to get medical supplies to the other side of a flooded river. You don't have a boat and only a limited number of supplies that include a small piece of rope that is not long enough to reach the other side. You also have access to a large plank of wood washed up by the flood and a log. Your mission is to devise a plan to get the medical supplies to the people on the other side of the river.

Materials

30-cm ruler
pencil or marker
foam cup
string
scissors
tape
10 mini marshmallows
goggles

Procedure

1. Sort through your supplies: goggles, ruler (large plank), pencil (log), string (rope), mini marshmallows (bundles of medical supplies), tape, foam cup, and scissors.
2. Brainstorm how you are going to get the medical supplies to the other side.
3. Construct your solution using only the supplies provided.
4. If you are able to move your supplies 20 cm or more, then you have successfully completed your mission. If your bundles fall short of 20 cm, then the supplies have washed downstream. The group who gets the most bundles across the river "wins" the competition.
5. Present your solution to the class and discuss how and why you used this solution.

Conclusion

1. In your solution, did applying a force in one direction cause a force in another direction?
2. What other simple machines can change the direction of a force?
3. Write a paragraph explaining your activity and how you used the items to move the medical supplies. Explain the forces used and their change of direction.

Answer Key

Popcorn, Get Your Popcorn Up Here!

1. The screw lifted the popcorn when it changed the rotation or twisting of the dowel into upward movement.
2. This device would be used today as a simple and inexpensive way to irrigate crops by using river and lake water. It is also used in combine harvesters to lift grain into storage containers.
3. Answers will vary.

Sizing It Up

1. Answers will vary.
2. Answers will vary.

Keeping It Simple

Inclined Plane

1. Yes.
2. The 30-dregree ramp used the least amount of force to lift the weight. When you increase the height of the ramp, you increase the amount of force necessary to move the weight. For example, if you have a 500-g weight at a 30-degree angle, it might take 125 g to move it up the ramp. However, when the ramp is set at 60 degrees, you have to overcome more height, which results in using more force.
3. The length of the ramp increased as the angle became smaller.
4. Answers will vary but might include that ramps can be used to move furniture, help make places accessible to people in wheelchairs, and help cars go up steep mountains.

Wedge

1. The banded blocks could not be separated with the smaller block of wood.
2. The wedge was able to get between the banded blocks and separate them unlike the block. The wedge is thinner on one end and that allows it to fit in small, tight places.
3. Answers will vary but might include splitting firewood, loosening boards on a fence, and prying hubcaps off a tire.

Wheel and Axle

1. The screwdriver with the larger handle.
2. The ratio between the handle (wheel) and the shaft (axle) is larger on the larger handled screwdriver. With a larger ratio, you divide the weight by a larger number and get a smaller amount of force needed.
3. Answer will vary but might include a Ferris wheel, wheelbarrow, and moving boxes on rollers.

Screw

1. Unlike the screws, the nail was unable to go into the wood.
2. Screw B went into the wood easier than screw A.
3. The difference between the two screws was the distance between the threads. Screw B's threads had a smaller distance between them.
4. It took more turns to get screw B into the wood because you had to turn it over a longer distance since the pitch was smaller. Even though you had to turn Screw B more times, it made the force less. That is called a tradeoff.
5. Answers will vary, but might include securing items to a wall, connecting the stems of eye glasses to the frames, and putting machines together.

Lever

1. Yes. The farther away from the dictionary the fulcrum was moved, the more grams of force it took to lift it.
2. To lift a heavy load, place the fulcrum close to the load.
3. Answers will vary, but might include a seesaw, moving large rocks, and lifting a heavy item to slide something under it.

Pulley

1. No. The amount of grams (force) used was the same.
2. The amount of force needed to move the load decreased when using the two-pulley system.
3. You can use one pulley to change the direction of the force. It is easier to pull down than to lift up, so this makes work easier.
4. Answers will vary, but might include loading containers on and off boats, lifting heavy objects up to a second story building, and taking a motor out of a car.

Mission Possible

1. The solution to this problem is probably going to be the construction of a catapult, using the plank and the ruler to launch the supplies to the other side. As force is applied to one end of the plank, it creates a force on the other end of the plank, moving in the opposite direction. This device will then launch the supplies through the air and hopefully, to the other side.
2. Many other simple machines can change the direction of a force. For example, when using a single pulley, you pull down to move the load upward. When using a wedge, you push down to move the load laterally. When using a gear, you turn one gear to move another gear in the opposite direction.

The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 3

The tree house detectives continue investigating pulleys, and Bianca continues researching various engineering careers for her presentation. Everyone is positive that pulleys are the answer to getting Jacob into the tree house. However, they are a little confused about how many pulleys to use. They decide to contact Ms. Gail Nowell's class, a NASA SCI Files™ Kids Club, in Raleigh, North Carolina. Now the tree house detectives think they have all the information they need to lift Jacob. Fortunately, they test their apparatus before putting Jacob in it, and they quickly realize that they have not considered safety features. The tree house detectives visit Ms. Rines, a safety engineer at NASA Langley Research Center in Hampton, VA. Ms. Rines suggests that they also need to consider human factors and sends them to see Dr. Kara Latorella, a human factors engineer, also with NASA Langley Research Center. Back at the tree house, the detectives have used their last pulley, but Jacob is still too heavy to lift. They stop by Dr. D's lab in hopes that he will be able to help them reduce the force needed to lift Jacob and to help them figure out what to do with all that rope from the pulley system.

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Objectives

The students will

- investigate how pulleys make work easier.
- design a safe and comfortable apparatus to lift a weight.
- understand how human factors affect the design of a product.
- construct a lever to lift a large weight.
- investigate the use of gears.
- understand friction.
- investigate changing technology through history.

Vocabulary

apparatus - the equipment or material for a particular use or job

compound machine - a machine consisting of two or more simple machines

gear - a toothed wheel that developed from the wheel and lever

human factors - study of how people behave physically and psychologically in particular environments and with certain products or services

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment, to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 3 of *The Case of the Powerful Pulleys*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 2 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 2. Use tools located on the Web, as was previously mentioned in Segment 1.
4. Focus Questions - Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.
5. What's Up? Questions - Questions at the end of the segment help students predict what actions the tree house detectives should take next in the investigation process and how the information learned will affect the case. These questions can be printed from the web site ahead of time for students to copy into their science journals.

View Segment 3 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. Have students reflect on the "What's Up?" questions asked at the end of the segment.
2. Discuss the Focus Questions.
3. Have students work in small groups or as a class to discuss and list what new information they have learned about work, energy, force, and simple machines. Organize the information, place it on the Problem Board, and determine whether any of the students' questions from Segment 2 were answered.

Careers

safety engineer
human factors engineer
structural design engineer
chemical engineer
architect

4. Decide what additional information is needed for the tree house detectives to determine what is the best method of getting Jacob into the tree house. Have students conduct independent research or provide students with information as needed. Visit the NASA SCI Files™ web site for an additional list of resources for both students and educators.
5. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
6. If time did not permit you to begin the web activity at the conclusion of Segments 1 or 2, refer to number 6 under "After Viewing" on page 13 and begin the Problem-Based Learning activity on the NASA SCI Files™ web site. If the web activity was begun, monitor students as they research within their selected roles, review criteria as needed, and encourage the use of the following portions of the online, Problem-Based Learning activity:

Research Rack - books, internet sites, and research tools

Problem-Solving Tools - tools and strategies to help guide the problem-solving process.

Dr. D's Lab - interactive activities and simulations

Media Zone - interviews with experts from this segment

Expert's Corner - listing of Ask-An-Expert sites and biographies of experts featured in the broadcast

7. Have students write in their journals what they have learned from this segment and from their own experimentation and research. If needed, give students specific questions to reflect upon, as suggested on the PBL Facilitator Prompting Questions instructional tool found in the educator's area of the web site.
8. Continue to assess the students' learning, as appropriate, by using their journal writings, problem logs, scientific investigation logs, and other tools that can be found on the web site. Visit the Research Rack in the tree house, the online PBL investigation main menu section "Problem-Solving Tools," and the "Tools" section of the educator's area for more assessment ideas and tools.

Resources

Books

Dahl, Michael: *Pulleys*. Bridgestone Books, 1996, ISBN: 1560654457.

Maynard, Christopher: *Jobs People Do*. DK Publishing Inc., 1997, ISBN: 0789414929.

Peterson, John Lawrence: *The Littles and the Trash Tinies*. Scholastic Inc., 1993, ISBN: 0590465953.

Seller, Mick: *Wheels, Pulleys, & Levers*. Gloucester Press, 1993, ISBN: 0531174204.

Web Sites

Marvelous Machines
A list of experiments for levers, wheel and axles, and inclined planes. http://www.henry.k12.ga.us/cur/simp-mach/resources.htm

Combined Pulley
An explanation about the advantages and disadvantages of pulleys, including a moving model. http://www.smartown.com/sp2000/machines2000/pulley4.htm

Mathematics Activities With Ropes and Pulleys
A series of three activities for students to explore the mechanical advantage of pulleys. http://www.cpo.com/CPOCatalog/RP/rp_math.htm

PBS Teacher Source—Mathematics of Bicycles
"Wheel Figure This Out" is an activity offered by PBS Teacher Source that builds mathematical skills by comparing various features of the bicycle. http://www.pbs.org/teachersource/mathline/concepts/neighborhoodmath/activity3.shtm

Activities and Worksheets

In the Guide

Powerful Pulleys
Investigate pulleys to find out if they really make work easier. 43

Safe, Sneaky Snacks
Design a safe apparatus to lift snacks to the playroom. 45

Keeping It Human
Learn how to use human factors in designing a product. 46

Load-Lifting Lever
Can you lift your teacher? Find out how in this activity! 47

Creative Gears
Create gear wheels to draw beautiful patterns. 48

Answer Key
..... 49

On the Web

That Sticky Friction
Investigate friction and how it affects our world.

A Bicycling We Will Go
Discover how the design of bicycles has changed over time as technology has developed.

Powerful Pulleys

Purpose

To understand that pulleys reduce the amount of force needed to lift an object

Materials (per group)

- two double pulleys
- string
- pennies
- cup with attached string
- clamp and poles from which to hang the pulley system
- 500 gram mass (weight)
- balance
- calculator

Procedure

1. Use a balance to find the mass of the bottom pulley system and the attached weight, which is called the load. Record the mass in the chart below.

Object	Mass
Load (Mass of pulleys + 500 g)	

2. Attach the string to the hook on the bottom pulley.
3. Loop the string over the top pulley and attach the cup to the string.
4. Hang the weight from the hook on the bottom pulley. (See Diagram 1)
5. Begin placing pennies in the cup, continuing until the cup balances the weight without anyone having to hold it.
6. Continue placing pennies in the cup until the cup moves. Note: If the cup begins to move and then stops, give the cup a little downward tap. If the cup resumes its motion and moves a good distance, don't add any more pennies. If the cup moves only a few cm and then stops again, you will need to add another penny or two until it moves with a little tap.
7. Place the cup with pennies on the mass balance and record its mass to the nearest gram. The mass of the pennies plus the cup is called the total mass.
8. Repeat steps 5-7 for three more trials and record results in data chart (p. 44). Before each trial, remove 5 or 6 pennies from the cup.
9. Find the average mass for the four trials and record in the data chart. Your answer should be to the nearest gram.
10. To repeat the experiment using 2 strings, attach the string to the top pulley, go around one bottom pulley and one top pulley and then attach the cup to the string. See diagram 2.
11. Now repeat steps 5 through 9 to determine the mass required to lift the load, when it is supported by 2 strings.
12. To find the mass required when using 3 strings, attach the string to the bottom pulley, go around one top pulley, bottom pulley, and the top pulley. See diagram 3.
13. Repeat steps 5 through 9.
14. To find the mass required using 4 strings, attach the string to the hook on the top pulleys and go around one bottom, followed by a top pulley, then the other bottom pulley, and finally the remaining top pulley. See diagram 4.
15. Repeat steps 5 through 9.

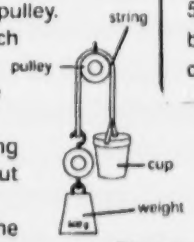

Diagram 1

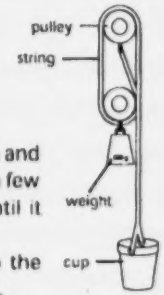

Diagram 2

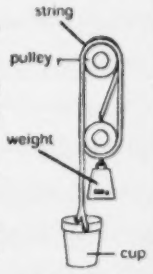

Diagram 3

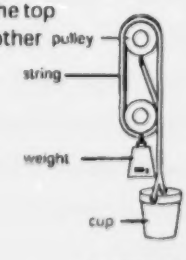

Diagram 4

Data Chart: Total Mass

Number of Strings	Trial 1	Trial 2	Trial 3	Trial 4	Average Total mass
Example:	212 Grams	213 Grams	211 Grams	212 Grams	212 Grams (212 + 213 + 211 + 212) ÷ 4
1 String					
2 Strings					
3 Strings					
4 Strings					

16. Share your results with the rest of the class and find the class average to the nearest gram.

Group Averages for Total Mass

	1 String	2 Strings	3 Strings	4 Strings
Group 1				
Group 2				
Group 3				
Group 4				
Group 5				
Group 6				
Class Average				

Conclusion:

1. Was the total mass required to move the pulley always less as the number of strings increased?
2. The theory states that the total mass required to lift the load with a pulley system can be found by dividing the load by the number of strings supporting the bottom pulley. Use a calculator to divide the load (Load = mass of bottom pulleys + 500 grams) by the number of strings in each experiment. Record the actual average total mass required to lift the load for each. Find the difference between the two numbers and record.

Number Strings	Load ÷ Number of Strings	Actual Total Mass	Difference
Example: 1	523 ÷ 1 = 523 g	554g	31g
1			
2			
3			
4			

How do you explain the differences between your class's experimental values for Total Mass and the values listed above for Load ÷ Number of Strings?

Safe, Sneaky Snacks

Purpose

To design a safe apparatus to lift a specified load

Teacher Note

Prior to performing the activity, you will need to construct a 10-cm x 30-cm x 3-m rectangular vent from cardboard for students to use for testing their apparatuses. Allow students one-two days to research and design an apparatus. Provide basic materials or have students bring supplies from home to complete their design. Rubrics and other evaluation tools are provided on the NASA SCI Files™ web site that may be printed and given to students for assessment.
http://scifiles.larc.nasa.gov/educators/index.html

Materials

science journal
eggs
metric rulers
encyclopedias
internet access
string
cardboard
shoe boxes
scissors
scraps of material
cotton
foam
glue
tape
thread spools or pulleys
plastic eggs

Procedure

Shannon and Blair are trying to sneak snacks up to their playroom without their little sister's knowledge. They have decided to set up a pulley system inside a 10-cm x 30-cm air-conditioning vent. The playroom is located 3 meters directly above the kitchen. They have to make sure that their snacks don't fall since the snacks are eggs! To help Shannon and Blair, you need to design an apparatus to lift the snacks quietly and safely.

1. In your group, discuss the situation, determine "what you know" and create a list in your science journal. To help in your design process, a copy of the Design Log can be obtained from the NASA SCI Files™ web site <http://scifiles.larc.nasa.gov/educators/tools/pbl/design_log.html>
2. Reach a consensus about "what you need to know" and conduct research using books, the Internet, and other available resources.
3. Design your apparatus, creating detailed drawings, descriptions, and a materials list needed for your design. Note: At your teacher's discretion, materials may be brought from home to help construct your apparatus.
4. Be sure that you have considered and addressed all the appropriate safety issues.
5. To construct your apparatus, gather the materials needed and work as a team to create a safe apparatus for your egg snacks.
6. Once the apparatus is completed, conduct a test run with a plastic egg to make sure your apparatus is safe for your real egg.
7. If problems are encountered in your test run, redesign and make changes as needed. Conduct a second test run. Repeat until test run is successful.
8. Lift your egg in the apparatus.

Conclusion

1. What safety precautions did you take to ensure that the egg would survive the trip up the vent?
2. What type of backup plan would you make if the apparatus fell down the vent past the kitchen and into the basement?
3. What materials worked the best in this project?
4. What materials are the safest?
5. How did your research help you design the apparatus?
6. How can the tree house detectives make their lift chair safer?

Extension

Test the students' apparatuses in an "egg drop" contest to see which ones best protect the egg from a fall.

Keeping It Human

Purpose

To understand human factors involved in designing a product

Materials

backpacks
weight scale
print resources
Internet
science journal

Procedure

The young astronauts' club has just received a grant to purchase laptop computers for each member of the club. However, the laptops are heavy, and your teacher is concerned that students may experience physical problems from carrying them to and from school each day. You and the other members want to enjoy your laptops at home each night, so you decide that you need to design a backpack that would both carry your laptop safely and keep you from being injured.

1. Visit Cornell University's Ergonomics Web site at <http://ergo.human.cornell.edu/MBergo/intro.html>, and/or conduct additional research by using other print and online resources.
2. Review what Dr. Latorella discussed with the tree house detectives about human factors.
3. Brainstorm various human factors that should be considered in designing a backpack.
4. Observe various backpacks and discuss the designs of each.
5. Discuss the amount of weight that will be carried in the backpack (laptop plus books, notebooks, and so on).
6. Explore the relationship between the weight of a backpack compared to the weight of the person wearing it. (Divide the weight of the backpack by the student's weight.)

Example:

Backpack weight	Body Weight	% of weight carried
22 kg	129 kg	17

7. Conduct research to determine what percentage is a safe amount to carry.
8. Calculate the amount of weight to be carried in the backpack and your weight to determine the percentage of weight to be carried. Is this a safe percentage?
9. Draw a detailed design of your backpack.
10. Share your design with the class and explain why you designed it as you did.

Conclusion

1. What is a safe percentage of weight to carry in a backpack?
2. Why is it important not to carry more than a certain amount of weight on your back?
3. What human factors did you consider in your design?

Load–Lifting Lever

Purpose

To help students understand that a lever can be used to lift a weight with less effort

Materials

2 in x 6 in x 6 ft board (5 cm x 15 cm x 180 cm)
small triangular block for fulcrum
marker
meter stick

Procedure

1. Measure the board and mark the center of the board with a marker.
2. Starting at the center of the board and working your way to one end, mark the board every 30 cm.
3. Label the center of the board "C." Label the next mark "1R," the third mark "2R," and the end "3R" (right side of the board).
4. Repeat for the other side of the board, labeling the marks 1L, 2L, and 3L (left side of the board). See diagram 1.
5. Place the triangular block (fulcrum) at the center mark of the board.
6. Place six same-sized textbooks (load) on mark 3R at the end of the board. This arrangement works best if you are able to "center" the books over the ends of the board.
7. Predict how many textbooks it will take to balance the load and record the number.
8. On the opposite end of the board at 3L, begin to stack the same-sized textbooks (force or effort) until the board balances. Record in data chart below.
9. Take all the books off the board.
10. Keeping the effort at the same place, repeat experiment with the load at a different point by centering the stack of six books (load) over mark 2R and by repeating steps 7-9. Note: To get the board to balance, you might need to adjust the position of the effort by a few centimeters.
11. Repeat steps 7-9, keeping the effort constant, but positioning the stack of books (load) over mark 1R.
12. Look at the data collected and find any patterns and/or relationships.
13. In the previous experiment, you moved the load closer to the fulcrum and applied the force or effort in the same place. Now you are going to keep the load constant and move where you apply force or effort. Predict any patterns that might be created and record in your science journal.
14. Place two textbooks (load) at the end of the board at mark 3R. Predict how many textbooks it will take to lift the load from the 2L mark. Record your prediction in your science journal.
15. Begin stacking textbooks (force or effort) at mark 2L, being sure to center them over the mark.
16. Continue to stack textbooks until the board balances. Record in data chart and take the books off the board.
17. Keeping the load at 3R, repeat steps 15-16 but this time center the books over mark 1L.

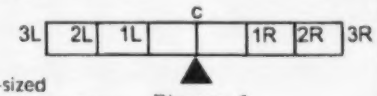

Diagram 1

Conclusion

1. What did the board represent? The triangular block? The six books lifted? The books used to do the lifting?
2. As you moved the load toward the center of the board, did it take more or fewer books to lift the six books (load)?
3. As you moved the force or effort toward the center of the board, did it take more or fewer books to lift the six books (load)?
4. In your science journal, create a graph of your data.

Data Chart

Effort at 3L—Load Varies	Prediction	Actual
3R		
2R		
1R		

Load at 3R-Effort Varies	Prediction	Actual
3L		
2L		
1L		

Extension

1. Predict where to place the fulcrum on the lever to lift your teacher. If your teacher will agree, test your prediction.
2. Research and explain Archimedes' Law of the Lever.
3. Research and explain the three classes of levers.

Creative Gears

Purpose

To use gears to make pictures and patterns

Materials

30-cm x 30-cm cardboard
drawing paper
colored pencils
corrugated cardboard
push pins
compass
scissors
glue
metric ruler
metric tape
35-cm x 35-cm foam board
various sized jar lids
nail
hammer

Procedure

1. Use the ruler to find the center of the 30-cm x 30-cm cardboard square.
2. Using the compass, draw a 22-cm diameter circle in the center of the cardboard.
3. Carefully cut out the circle to create a hole in the cardboard.
4. Use the tape to measure the circumference inside the circle.
5. Cut a strip of corrugated cardboard the circumference of the hole and 2 cm wide.
6. Glue the strip to the edge of the hole so that the corrugations face outward. Make sure that one edge of the strip is level with the edge of the hole. See diagram 1.
7. To create gear wheels, use the tape to measure the circumference of each lid.
8. Cut strips of corrugated cardboard to fit the circumference of each lid by 2 cm wide.
9. Glue strips onto the outer edge of each lid with the corrugation facing outward.
10. Using a nail, make 3-4 holes at different distances from the center in each lid. The holes need to be large enough for the point of your pencil to fit through.
11. Place a sheet of drawing paper on the foam board.
12. Place the corrugated cardboard square on top of the paper and use push pins to secure it in place.
13. Choose a gear wheel (lid) and place it on the drawing paper in the hole in the cardboard.
14. Choose a colored pencil and place the point through one of the holes in the gear wheel so that it touches the paper.
15. Hold the foam board firmly with one hand and use the pencil to push the gear wheel around the inside of the large hole. See diagram 2.
16. Continue to use different gear wheels and different colored pencils to create beautiful patterns and designs.

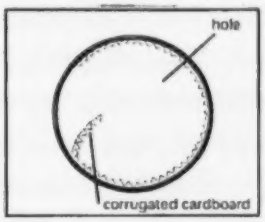

Diagram 1

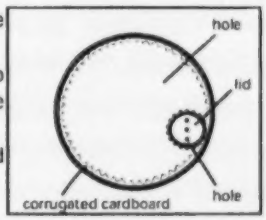

Diagram 2

Conclusion

1. Some patterns will repeat after just a few turns, while others may take many turns before they start again. Describe how you created patterns by using each gear wheel.
2. Explain how the number of teeth on the gears and the position of the pen hole affect the pattern.
3. What variables could you change to create different patterns?

Answer Key

Powerful Pulleys

1. Yes.
2. Answers will vary.
3. The difference between the two numbers is due to friction. Friction affects the amount of pennies needed to lift the mass and pulley. To overcome friction, more pennies must be added.

Safe, Sneaky Snacks

Answers will vary, but students should include safety measures that address the egg not rolling out of the apparatus, the apparatus not slipping, protection for the egg if the apparatus does fall, and any other criteria necessary.

Keeping It Human

1. 15 %
2. It is important not to carry more than that amount of weight on your back because additional weight can cause back injuries or stress to the spinal cord.
3. Answers will vary but might include the width of the straps, the ability to adjust the straps, the material the backpack is made of, and so on.

Load-Lifting Lever

Data Chart

1. The board represented the lever, the block was the fulcrum, the six books were the load or resistance,

Position of Load	Actual
3R	6
2R	4
1R	2

Position of Force/Effort	Actual
3L	2
2L	3
1L	6

the books used to do the lifting were the force or effort needed to lift the load.

2. As you moved the triangular block (fulcrum) toward the end of the board (load), it took fewer books (effort) to lift the six books.
3. It took more books to lift the load as you moved toward the fulcrum. If your force is 5 times further from the fulcrum than the load, then you multiply the force 5 times. The trade-off is that the distance you have to push down will be 5 times greater than the load distance (how far it moves up).
4. Graphs will vary.

Creative Gears

1. Answers will vary.
2. Answers will vary.
3. Some variables that can be changed to create different patterns are the size of the large hole, using different holes in the gear wheel, and using different sizes of gear wheels.

On the Web

That Sticky Friction

1. When you rubbed your hands together, you felt them get hot. Friction produces heat.
2. The rubber band should stretch longer when the box is resting on the flat surface. The flat surface should be the roughest surface and therefore have the most friction.
3. More force was required to start the box on the flat surface because the flat surface was the roughest surface creating the most friction. It takes more force to overcome more friction.
4. Lubricants reduce the amount of friction between two objects.
5. Answers will vary but might include motor oil, petroleum jelly, and grease.
6. Friction will increase the amount of force needed for the tree house detectives to lift Jacob with the pulley system.

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The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 4

The tree house detectives have finally found the solution to lifting Jacob safely into the tree house...pulleys. However, they still don't have an adequate number of pulleys to reduce the force sufficiently to make lifting Jacob easy for them, and they can't figure out what to do with all that rope! While on vacation, Anthony visits Legoland® to learn about gears and decides that gears are the answer. Now the detectives think they have not only solved the problem of force, but that they have even solved the problem of too much rope. As Bianca wraps up her career day presentation, the tree house detectives finish building their lift apparatus. Finally, they lift Jacob successfully into the tree house! However, there is just one small problem....

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Objectives

The students will

- determine how the number of teeth on a gear reduces the amount of force.
- compare the length of the handle of a winch to the spool to determine the decreased amount of force.
- discover what materials are used to overcome friction.
- create a way to get Jacob down from the tree house.
- create a compound machine to complete a task.

Vocabulary

belay - to make (as a rope) tight by turns around a cleat or pin

Imagineer – a person who works at Legoland®, CA designing and creating Lego® models

ratchet - a mechanical device that consists of a bar or wheel having slanted teeth into which a pawl (hinged or pivoted catch) drops so as to allow motion in one direction only

Video Component

Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 4 of *The Case of the Powerful Pulleys*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 3 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 3. Use tools located on the Web, as was previously mentioned in Segment 3.
4. Focus Questions-Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.

View Segment 4 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. At the end of Segment 4, lead students in a discussion of the focus questions for Segment 4.
2. Have students discuss and reflect upon the process that the tree house detectives used to design a safe lifting apparatus for Jacob. The following instructional tools located in the educator's area of the web site may aid in the discussion: Experimental Inquiry Process Flowchart and/or Scientific Method Flowchart.
3. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
4. Wrap up the featured online Problem-Based Learning investigation. Evaluate the students' or team's final product generated to represent the online PBL investigation. Sample evaluation tools can be found in the educator's area of the web site under the main menu topic "Tools."

2001 - 2002 NASA "Why?" Files Programs

5. Have students write in their journals what they have learned about simple machines, force, friction, and/or the problem-solving process and share their entry with a partner or the class.

Resources

Books

Baker, Wendy and Andrew Haslam: *Make It Work! Machines.* Thomson Learning, 1994, ISBN: 1568472560.

Burton, Virginia Lee: *Mike Mulligan and His Steam Shovel.* Houghton Mifflin Company, 1977, ISBN: 0395259398.

Gardner, Robert: *Science and Sports. F. Watts,* 1988, ISBN: 0531105938.

Morgan, Sally and Adrian: *Designs in Science: Using Energy.* Facts on File, Inc., 1993, ISBN: 0816029849.

Careers

Imagineer
rock climber
electrical engineer
structural engineer

Web Sites

Lego® Just Imagine
Explore the world of Legos® and Legoland®. This web site has interactive games, adventures, and even a Kids' club.
http://www.lego.com/

Those Crazy Lego® Screws!
Read an in-depth explanation of the screw and take a look at three examples made from Legos®.
http://weirdrichard.com/screw.htm

Inventor's Toolbox: The Elements of Machines.
See real-life pictures of simple machines with descriptions and examples.
http://www.mos.org/sln/Leonardo/InventorsToolbox.html

Activities and Worksheets

In the Guide

Get Your Gears Here!
Create a set of gears to discover how they work 54

Crank It Up!
Learn to use a crank handle to lift objects 55

Fighting Force of Friction
Learn how different materials affect the amount of force needed to overcome friction 56

Simply Words
Hunt for words in a "simple machines" word find 57

Vocabulary Crossword Puzzle
Create your own crossword puzzle using words related to simple machines 58

Answer Key
..... 59

On the Web

Get Me Down From Here!
Help devise a system to get Jacob down from the tree house

Get Your Gears Here

Purpose

To understand how gears work

Procedure

1. Choose several different sized jar lids and measure the circumference of each. Record in your science journal.
2. Cut strips of corrugated cardboard 1.5 cm wide by the length (determined by the circumference) for each lid.
3. Count the number of "teeth" (ridges in the cardboard) for each strip. If there are an odd number of teeth, cut one tooth off to make it an even number.
4. Carefully stretch the cardboard so that the teeth are facing outward and are evenly spaced around the edge of the lid. Glue into place. See diagram 1.
5. Glue a small wooden dowel to the edge of each gear. See diagram 2.
6. Once the glue is dry, use a compass to find the center of the lid.
7. Use a small nail and hammer to make a hole in the center of the lid.
8. Using the push pins, pin the gears to the foam board so that the teeth of each gear mesh with the teeth of another gear. The gears should spin freely and be arranged in order from smallest to largest.
9. Use a marker to mark a starting point for each gear. Line the dowel up with the marker. See diagram 3.
10. Experiment with turning the gears and observe what happens.
11. Record your observations in your science journal and answer the conclusion questions.

Conclusion

1. When you turned the largest gear, what happened to the two smaller gears?
2. Which way did they turn?
3. Which gear did a complete turn first?
4. When you turned the smallest gear, did the largest gear turn more quickly or more slowly?
5. Turn the smallest gear one complete turn and count the number of teeth that pass the starting point for the middle gear and for the largest gear. What can you conclude from this comparison?

Extensions

1. Find objects such as a hand-powered eggbeater, bicycle, clock, and so on that use gears. Observe how they work.
2. Count the teeth in both sprocket wheels of a bike. Predict how many turns the rear wheel will make for every turn of the pedals. What would happen if a smaller sprocket were used on the rear wheel?
3. Tie a ribbon around a spoke of a bike's rear wheel. Predict how many turns the wheel will make as the pedals go around once. Turn the bike upside down and turn the pedal once.

Materials

corrugated cardboard
jar lids of different sizes
push pins
foam board (15 cm X 30 cm)
2-3 cm dowel pegs
glue
metric measuring tape
small nail
hammer
marker
science journal

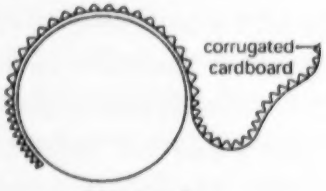

Diagram 1

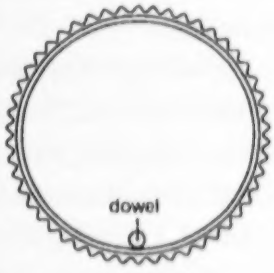

Diagram 2

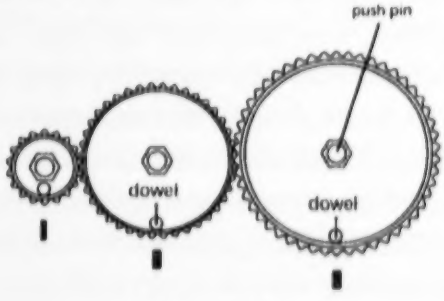

Diagram 3

Crank It Up!

Purpose

To use a crank handle to lift an object and determine the force

Materials

- pencil sharpener attached to wall
- 3-m string
- small weight
- scale
- metric ruler
- 20-cm dowel
- duct tape
- science journal

Procedure

1. Use the scale to weigh the load and record weight in science journal.
2. Remove the cover of the pencil sharpener.
3. Measure to determine the radius of the pencil sharpener barrel and record it in science journal.
4. Measure the length of the crank arm and record.
5. To determine the ratio between the crank arm and the barrel, divide the length o˙ the crank arm by the radius of the barrel. Example: 10/2 = 5/1 or 10 cm ÷ 2 cm = 5. The ratio is 5 to 1 (5:1). The ratio means that for every unit of force you apply, it is multiplied five times with the crank arm. Calculate your ratio and record.
6. Securely tie one end of the string to the barrel.
7. Tie the other end of the string to the weight (load).
8. Turn the handle of the pencil sharpener (crank) to lift the load to the top.
9. Lower the weight to the floor.
10. To calculate how much force you used to lift the load, divide the weight by the amount your force was multiplied (ratio). Calculate and record.
11. Using tape, secure the dowel to the crank arm to extend the arm.
12. Calculate the ratio and find the amount of force needed to lift the load with the longer crank arm.
13. Repeat steps 8-9 and record your observations.
14. Going just by how it felt, compare the force you exerted in steps 8-9 and in step 13. Record your observations.

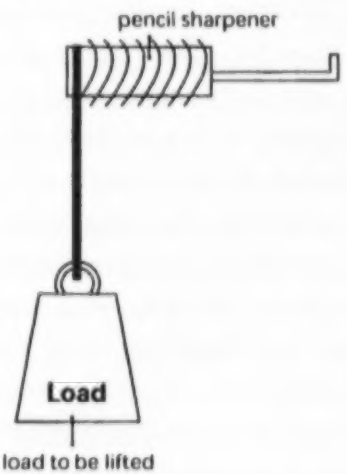

Diagram 1

Conclusion

1. Describe the simple machines used and explain how they work together.
2. How much did the force increase when the crank arm was extended?
3. You exerted less force in step 13. What is the trade-off?
4. List and describe other machines in everyday life that use a crank to make lifting easier.

Fighting Force of Friction

Purpose

To learn how different materials can affect friction
To investigate the amount of force needed to move an object

Materials

spring scale
4 different soled shoes
various sized washers
waxed paper
sandpaper
tape
balance

Background

Friction happens when objects rub together. As the tree house detectives calculate the force needed to get Jacob into the tree house, they have to consider friction as an opposing force. The ropes rubbing against the pulleys cause friction that must be overcome. Though friction is always a factor in the amount of force needed to move objects, there are ways that friction can be reduced so that the amount of force needed is also reduced.

Procedure

1. Measure 30 cm of waxed paper. Tape the paper to a flat surface such as a table.
2. Measure 30 cm of sandpaper. Tape the sandpaper along the side of the waxed paper.
3. Label the shoes from A-D.
4. Using a balance, find the mass of each shoe and record.
5. Determine which shoe has the most mass and calculate how much mass needs to be added to the other shoes to make them all equal.
6. Use the balance to find the number of washers needed to add to each shoe so that they are all of equal mass.
7. Place the correct number of washers in each shoe.
8. Place the toe of shoe A on the far edge of the waxed paper and connect the spring scale to the heel of the shoe. See diagram 1.
9. Making sure that the spring scale is parallel to the flat surface, slowly pull the shoe forward across the waxed paper.
10. Read the measurement on the spring scale just as the shoe begins to move and record in data chart.
11. Repeat steps 8-10 using the sandpaper.
12. Repeat steps 8-10 with each of the different shoes.
13. Rate your shoes from the ones that required the least amount of force to move to those that required the most force.

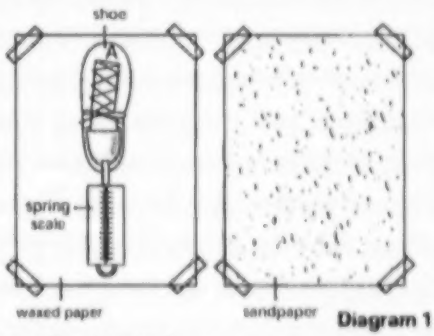

Diagram 1

Data Chart

				Force on Flat Surface	
Shoe	Type of Sole	Mass	Number of Washers Needed	Waxed Paper	Sandpaper
A					
B					
C					
D					

Conclusion

1. What are some differences in the shoes that required more force to those that required less force?
2. How do the soles of some shoes create more friction than others?
3. How did the force required for each shoe differ between the waxed paper and the sandpaper?
4. Which shoe required the least amount of force? Why?
5. Usually friction is thought of as a negative force that must be overcome to do work. What are some positive characteristics of friction in daily life?

Extension

1. Gather each group's results and create a class chart or graph. Analyze and discuss the findings.
2. Use shoe boxes and add water, oil, salt, and so on to the waxed paper to determine the difference in the amount of force needed.

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Simply Words

Word Bank

inclined plane	screw	wedge	pulley	wheel and axle	fulcrum	load
force	lever	kinetic	potential energy	crank	winch	work
gears	teeth	machine	compound	friction	push	pull
apparatus	system					

I N C L I N E D P L A N E A P P A R A T U S
S N M O S P S M F I B A B E H U G U Y I N I
G A C A M O R P D O V C A C X L R O L M D T
I B F D E P E R I A K M E I C L I P E O E P
P N S A A I O M B N H T I H B E L C H T R O
F H E D L T I U A I R A U X S Y L I S H R T
G K A I W O R K N K I N E T I C I I I Y O E
C J I L I E S N M D C J I L P L L E U D O N
B L S T Y I D J T Y B L S T U T A G O R F T
Z A I E H E R G E H Z A I E S I R V A I M I
S S M W E T I P E I T E E T H S C A R E D A
Q Z Q U I C K I A T O M M Y F R T E P U L L
R N L D S H I N D F R I C T I O N I T I X E
Y G E A R S Z A I O V C O U R T N E Y A I L
K I V N R T S S M R P I D N A I E N D J K E
J S E Y K O Q Z Q C Y I Y I I M W N B O N I
H F R T J B S C R E W P E L L A A I I D A U
P E N E R G Y A E R T R K C I L A C S T R Y
U E R E P G S I D K Z U A A E R I S H I C T
Y K O T I I T G A D T B I E B I L L I I I S
T J B E S B E K I S R I H Y O T J A C O N I
S A E M A I M O H T A W P F I S L I Z Q U E
I G W I N C H E N N Y N I K K I N Y I R P V
O F A E B Z X R Q W R O R L F U L C R U M E

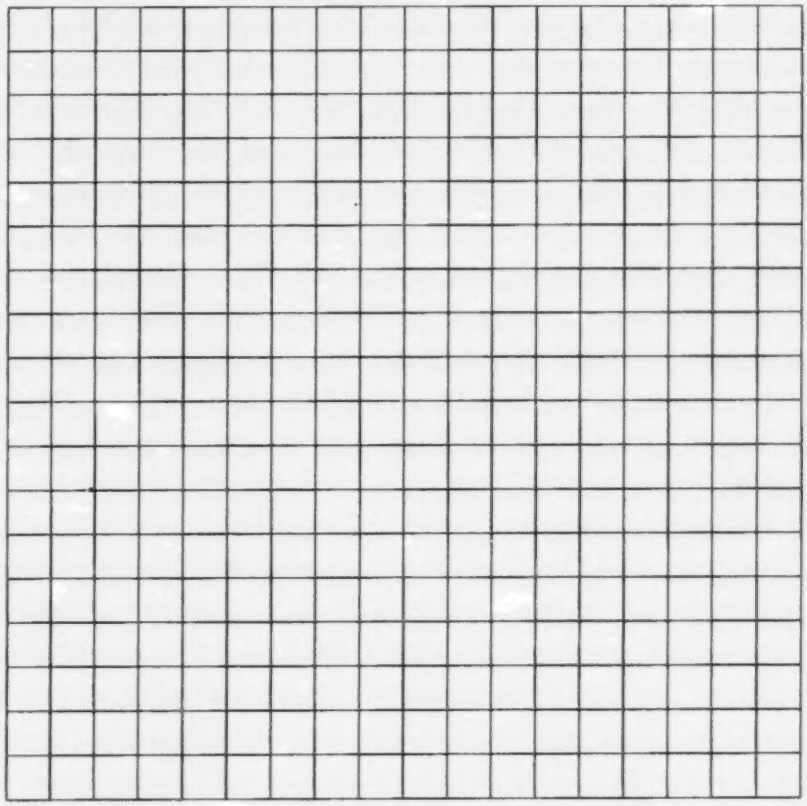
Vocabulary Crossword Puzzle

Create your own crossword puzzle using the key science vocabulary words from the program.

Vocabulary

inclined plane, screw, wedge, pulley, wheel and axle, fulcrum, force
lever, kinetic energy, potential energy, gears, friction

Some of your own: _____



Down

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____

Across

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____

Answer Key

Get Your Gears Here!

1. The two smaller gears also turned. The smallest and middle gear turned more than the largest gear.
2. The middle gear turned in the opposite direction of the largest gear, and the smallest gear turned in the same direction as the largest gear.
3. The smallest gear.
4. More slowly.
5. Students should see that if you have twice the number of teeth on the larger gear than on the smaller gear, then the smaller gear will turn twice as fast, thus the speed of the gear doubles.

Crank It Up!

1. The simple machines used here are a wheel and axle and a lever. A crank is the handle that is connected to the axle. It is used to transmit motion.
2. The force was increased.
3. The trade-off is that you exerted the lower force over a greater distance as you moved through a greater circle. However, you did the same amount of work.
4. Answers will vary.

Fighting Force of Friction

1. Answers will vary, but should focus on the difference in the soles of the shoes.
2. A heavy, textured sole such as a cleat would create more friction than a smooth leather sole.
3. The smooth texture of the waxed paper decreased the amount of friction between the sole of the shoe and the waxed paper. A decrease in friction also caused a decrease in the force needed to move the shoes. Due to the rough texture of the sandpaper, friction increased; therefore, the amount of force needed also increased.
4. Answers will vary. Answers should focus on the soles of the shoes, the type of material the sole is made of, and the texture of the sole (cleat, roller blade, leather sole, rubber sole, and so on).
6. Answers will vary but might include tire treads that are used to grip a slippery road and the friction required to keep an elevator from slipping.

Simply Words

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